Work–Integrated Learning in Engineering, Built Environment and Technology:

Diversity of Practice in Practice

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Chapter 7
Running a Successful Practice School:
Challenges and Lessons Learned

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ABSTRACT

The Chemical Engineering Practice School (ChEPS) at King Mongkut's University of Technology Thonburi (KMUTT) in Bangkok is a two-year international curriculum modeled after Massachusetts Institute of Technology's School of Chemical Engineering Practice. The aim of this Master's program is to produce professional chemical engineers with strong fundamentals, practical experience, and a good command of English. The program's uniqueness lies in its strong linkage with the industrial sector. This chapter contains a history of ChEPS and details how KMUTT operates the program. The key factors contributing to the success of the program are identified. Moreover, critical analyses gleaned from the faculty, the alumni, and the industrial sponsors are carried out to examine the current strengths of ChEPS and to identify areas for improvement. Key challenges still facing the program are also outlined. Finally, potential solutions to these challenges are recommended.

INTRODUCTION

The traditional method of learning in engineering disciplines involves classroom lectures, homework assignments, and laboratory work. Although this training is effective to a certain extent, there exists a gap in the skill set needed of students when they step into the real world. This is particularly true in Southeast Asia including Thailand, where education has traditionally been more tightly structured and teacher-directed (Ziguras, 2001). Rote learning is usually the norm, and creative thinking

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is often overlooked. *Spoon-feeding* is prevalent in classrooms even at the college level. As a result, engineering graduates in Thailand generally do not possess strong analytical and problem-solving skills. To compensate for the deficiencies in the educational system, companies are often forced to invest substantial resources on re-education and on-the-job training for starting engineers.

In addition, the English proficiency of Thai engineering students is on the average subpar. In today's global economy and with a substantial foreign investment totaling billions of dollars annually in Thailand, the importance of English cannot be overemphasized. Unfortunately, English takes a backseat in most engineering curricula. Students have very limited exposure to English, and there is little incentive for them to improve, as most programs do not have a minimum English requirement for graduation. Finally, companies often complain about the inadequate training of university graduates in communication, be it spoken or written, even in their native language. These facts are hardly surprising, given that nearly all graduate programs are taught in Thai with little emphasis on technical writing and oral presentations.

King Mongkut's University of Technology Thonburi (KMUTT) is an autonomous state institution in Bangkok with a long tradition in engineering. As early as 1996, the university recognized many shortcomings described above in its engineering programs. Shortly after, KMUTT introduced an initiative to develop a new flagship practice-based curriculum aimed at overcoming these deficiencies. The objective was to produce well-rounded engineers who possess strong technical expertise, can communicate effectively, and have good English proficiency. If proven successful, the goal was to expand the initiative to include other curricula. KMUTT chose Chemical Engineering to be the pilot program. The new curriculum called the Chemical Engineering Practice School (ChEPS) was founded in 1997 and modeled after Massachusetts Institute of Technology's (MIT) David H. Koch School of Chemical Engineering Practice. ChEPS is a two-year international master's program with one semester of compulsory industrial internship or practical training.

The practice school can be viewed as one model of Work-Integrated Learning (WIL), which can be broadly defined as educational activities that integrate theoretical learning with its application in the workplace. This learner-centric process should provide a meaningful experience of the workplace application, resulting in successful learning outcomes such as problem-solving skills, creative thinking, and other soft skills for the student. WIL models include (but are not limited to):

- Practical training via practice schools
- Internships
- Work placements
- Cooperative education
- Industry-based learning
- Community-based learning
- Student group projects

The essence of a practice school is to supplement traditional classroom learning and "instructionism" with practice-based learning (PBL) and "constructionism", which together can be succinctly described as "learning by doing." This learning takes place at industrial sites in a real work environment where students are trained to solve real-life problems. In the practice school, this practical training is an integral and compulsory part of the curriculum and earns credit hours for students to fulfill their graduation requirement.

Practice-based learning is a new pedagogy and has been found highly effective for teaching science and engineering. In higher education, well-organized PBL can tremendously benefit the three primary stakeholders, namely the university, the student, and the industry. With practice-based curricula, the university fosters strong ties with industry and is able to graduate engineers with robust skills and practical experiences. On the other hand, students understand and appreciate theories taught in classrooms better and develop strong problem-solving skills when immersed in an authentic work environment. As a result, students graduating from such programs tend to have higher self-esteem and self-confidence. Finally, industry also has a lot to gain when hiring engineers and researchers with practical experiences, because they have a relatively short learning curve and adjustment period.

It has been 14 years since the inception of ChEPS. As with any new enterprises, the road to success in creating and running the practice school at KMUTT is not without difficulties. While the ChEPS program is now tremendously popular among graduates with bachelor's degrees in chemical engineering, there is still room for improvement. There also remain challenges and hurdles which need to be overcome. Moreover, the concept of practice-based curriculum is beginning to gain traction in Thailand, both at the secondary school and in higher education levels. More educators and academics have come to espouse this new learning model. As a result, more engineering departments around the country are opening up their own practice schools, and competition for top students and for funding will certainly intensify in the years to come. To avoid complacency and resting on past laurels, steps should be taken to continually adapt and improve the program to meet the changing needs of students and industries.

This chapter contains a history of ChEPS and detailed information about how the program is operated. Moreover, critical analyses gleaned from the experiences of the faculty and interview with ChEPS's alumni and industrial sponsors are carried out to examine the current strengths and key challenges still facing the program. These difficulties are collected and will be presented as lessons learned. Each lesson examines what the program is doing right and presents future challenges. Finally, potential solutions to the problems are also suggested.

BACKGROUND

MIT is probably the pioneer in fostering learning within industrial settings, and its chemical engineering practice school is the oldest in the world. The Practice School at MIT (Mattill 1991, 2010) was established in 1916 with the goal of supplementing classroom studies with practical training in an industrial environment. The program was widely regarded as the educational "flagship" of MIT and was considered a resounding success after just a few years of operation. The Practice School at the graduate level is truly unique in the US and is found only at MIT, although in recent years, the program has expanded to international stations such as Japan (O'Connor *et al.*, 1999) as well as offering a dual-degree master's with National University of Singapore. At present, the Department of Chemical Engineering at MIT offers two parallel master's programs: a traditional thesis-based curriculum and a practice-based curriculum. Students who choose to enroll in the latter are required to do two academic semesters of coursework, followed by an additional term of industrial internship. This internship replaces the research thesis found in a conventional master's program. A Master of Science in Chemical Engineering Practice (M.S.CEP) degree is granted upon graduation. Graduates of the MIT's Practice School are some of the most sought-after engineers in the country.

Inspired by the success of MIT's learning model, educators around the world went on to create a number of practice schools, some of which are well-established now. Birla Institute of Technology & Science (BITS) in Pilani, India, operates an undergraduate practice school which encompasses all disciplines of engineering, science, and humanities (2010). In fact, BITS operates two programs of Practice School (PS), namely PS-1 and PS-2. The difference between the two programs is that the duration of internship for PS-1 is eight weeks while that of PS-2 is six months. PS-1 aims at orienting students to the professional world using national laboratories, financial institutions, R&D centers, software and healthcare organizations as practice stations. On the other hand, students in PS-2 are drawn from different disciplines, work on a much longer period on a variety of professional activities in the industrial world, and are involved in problem-solving efforts of direct interest to the host companies.

Manipal Institute of Technology, one of the constituent colleges of Manipal University (MU), in Manipal, India, has also incorporated the practice school into its engineering curricula since 2005. The internship is optional for undergraduates, but when chosen, must be at least 16 weeks long. For the graduate courses, the internship period is one full year. The percentages of students in 2009 (50.1%) and the previous year (48.0%) opting for Practice School show the popularity of the program among students (2010).

At the urging of the UK government, the Cambridge-MIT Institute (CMI) was established in 2000 at the Cambridge University to explore how academics, industrialists and educators could work together to stimulate competitiveness, productivity, and entrepreneurship in the UK. The aim of CMI serves to enhance competitiveness and innovation by improving knowledge exchange between universities and industry. Six innovative new interdisciplinary master's programs integrating science, technology, and management studies were created. Between 2000 and 2006, CMI graduated more than 350 students from these curricula. CMI issued two reports titled *Accelerating Innovation by Crossing Boundaries* and *Working in Partnership* which summarized its activities and output between 2000 and 2006. The reports can be downloaded from CMI's website (2010).

The Department of Chemical Engineering at the University of New Brunswick (UNB), Canada, offers a course called Chemical Engineering Practice School, a two-week industrial project elective which exposes students to the practical aspects of chemical engineering. Groups of students, with faculty supervisors, are assigned to engineering projects to be carried out on industrial process units. Students are required to present an oral report to plant operating and technical personnel at the end of the practice session. A written report is also required. Bendrich and Pugsley (1998) presented an approach for introducing students at UNB to real industrial problems in this industrial project course.

The Professional Engineering Placement Scholarship (PEPS) is a work-based learning program that allows final-year engineering students the University of Queensland (UQ) in Brisbane, Australia, to spend up to six months in industry while still gaining full academic credit (2010). The program is open to all engineering students taking courses in mechanical, chemical, mechatronics, mechanical/aerospace, electrical and software engineering. A similar program called PIPS (Professional Information Technology Placement Scholarship) gives final-year information technology students a chance to work in the IT industry (2010).

Through a program called Co-operative Education for Enterprise Development (CEED), Corporation Technologies Pty Ltd (2010) links students from three of Queensland's major universities, namely the University of Queensland (UQ), Queensland University of Technology (QUT), and the University of Southern Queensland (USQ), with companies and government in industry-based projects. Real-life projects are completed by students as part of their university degrees – final-year undergraduate, Masters, or Honours. Starting in 2010, the School of IT at the University of Sydney (USyd) also joined the program. CEED provides clients with a wide variety of talented students in the fields of engineering, IT, business (marketing, human resources, and finance), mathematics, and science (biotechnology, biology, and computing science) for their projects, while companies provide training and mentoring to these emerging professionals.

Victoria University in Melbourne, Australia, introduced PBL into engineering curricula in its

Schools of Architectural, Civil, and Mechanical Engineering in 2006 (Rojter, 2007). In 2010, the university implements a new PBL model for all of its Bachelor of Engineering courses (2010). The model allows students to work on small problems in year 1, community and/or industry projects in years 2 and 3, and engineering practice on industrial projects in year 4. The PBL model emphasizes active learning as well as other skills such as creativity and problem solving, interpersonal and team working, business and project management, and communication in all forms.

The Manufacturing Engineering Education Partnership (MEEP) is a unique collaboration of three major universities, namely Penn State University, University of Puerto Rico - Mayaguez, and the University of Washington. MEEP is partnered with a premier high-technology government laboratory named Sandia National Laboratories, nearly 100 corporate sponsors covering a wide spectrum of US industries, and the federal government who funds this project through the Technology Reinvestment Program (TRP). MEEP's mission is to develop and implement a new curriculum in design and manufacturing that has strong collaboration with industry. The product of this effort is called the Learning Factory, an outcome-driven program which has been successfully institutionalized at the three participating universities. Critical emphasis is also given to the development of "soft skills" such as problem solving, communication, and teamwork. Lamancusa *et al.* (1995) described the Learning Factory and presented the results from the first year of its existence.

Since the industry-based learning has been incorporated into many engineering curricular worldwide, several papers have been published on the effectiveness and outcome of such a teaching model. For example, Lamancusa *et al*. (1997) described how industry-based projects were integrated into academia with respect to the Learning Factory at Penn State University and some of the successes and failures in this effort. The target curricula consisted of mechanical engineering, industrial engineering, and electrical engineering, all at the undergraduate level. Morell *et al*. (1998) discussed assessment instruments and tools designed to evaluate the overall curricular outcomes of the Learning Factory in MEEP, including student performance such as teamwork, oral presentation, and written skills. The assessment used the ABET Engineering Criteria 2000 (EC-2000), an accreditation standard that promotes innovation and continuous improvement in engineering education, as the benchmark. ABET EC-2000 contains an outcome assessment plan that requires engineering programs to have in place a continuous process of evaluation, feedback, and continued improvement of their effectiveness. The authors concluded that the Learning Factory did comply with the ABET EC-2000. In another work, Morell *et al*. (1998) presented how MEEP designed the assessment strategy to evaluate outcomes of industry-based curricula and some of the assessment instruments and tools designed. A list of detailed assessment instruments in the form of questionnaires and evaluation sheets in areas such as oral presentation, written report, industry survey, student survey, quality of teaching, and skills knowledge was also presented. More recently, Lock *et al*. (2009) explored the attitude of undergraduate engineers towards work placements in industry and assessed the placement experience in terms of student learning outcomes and future employment aspirations by collecting both quantitative and qualitative data via survey.

It is obvious that in addition to knowledge, a well-rounded professional engineer should possess a number of additional attributes that society and employers need (Ramirez & Beauchamp, 1995). KMUTT has long recognized the importance of such skills development, which include areas such as problem-solving, self-learning, communication, English proficiency, teamwork, leadership, and social responsibilities. When KMUTT initiated the practice-based curriculum in Chemical Engineering in 1997, it was decided that the new academic program must meet the following criteria:

- *Be international*. Lectures and presentations must be conducted in English. Reports and homework assignments are written in English as well.
- *Be a graduate program*, so that it is small enough and can be efficiently managed.
- *Be practice-based*, i.e. the curriculum includes one semester (five months) of compulsory industrial internship in which practice-based learning (PBL) is emphasized.
- *Has strong linkages to the private sector*, which offers industrial sites needed for practical training.
- *Has adequate funding* to attract top-notch students.

The David H. Koch School of Chemical Engineering Practice at Massachusetts Institute of Technology (MIT) in the US offered all the desired components that KMUTT sought in its curriculum. Contacts were subsequently made at the highest level between KMUTT and MIT to import the practice-school model into Thailand. MIT was retained as an advisor, and professors from its practice school traveled to Thailand to help set up the program, assess its readiness, and teach selected courses. The first class of ChEPS consisted of 21 students, all with undergraduate degrees in chemical engineering, who were recruited from universities all over Thailand. In subsequent years, 15 - 29 students were admitted annually. Ku *et al.* (2005) gave a comprehensive review of the ChEPS program.

Figure 1 illustrates the four essential components in the practice school, namely the university, the funding agencies, the students, and the industrial linkage. The funding agencies are state, semi-private, and private organizations, which provide research grants and scholarships to academic programs. ChEPS has relied heavily on such agencies for financial support in its operations, particularly during the early years. In a traditional graduate program, the industrial component is normally missing or its role is limited. On the other hand, industrial involvements are vital to the success of a practice school to ensure that students are trained to solve real-life problems early in their studies. These industry-relevant problems are identified by industrial sponsors, and are either brought to the classroom as case studies or solved as site projects during internships.

The ChEPS curriculum consists of one academic year (two semesters and one summer) of coursework, one semester of internship at a practice site, and one semester of research, as illus-

Figure 1. The four essential components of ChEPS

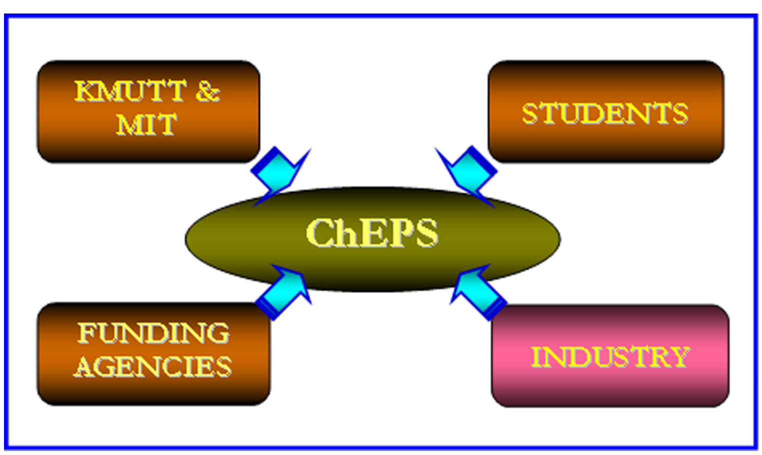
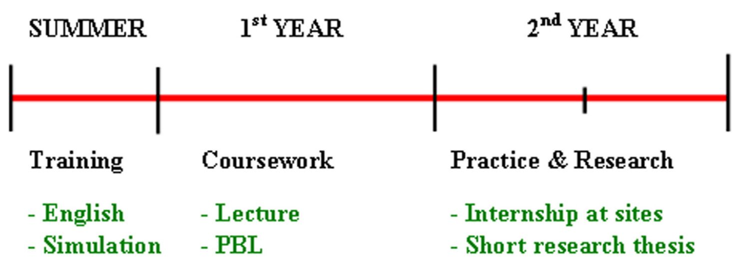


Figure 2. Timeline of ChEPS curriculum



trated in Figure 2. The coursework is fixed and there are no course electives. One objective when starting ChEPS was to introduce Western-styled learning into Thai classrooms. The ChEPS curriculum emphasizes both problem-solving and intensity. The whole program can be viewed as a *learning boot camp*, where problem-based learning is emphasized and students are constantly challenged to solve problems in real plants, sometimes with limited data and many constraints.

Course lecturers consist of both local and overseas instructors, including professors from the US, Canada, Australia, and Singapore. First-year courses comprise the following core subjects:

- Advanced thermodynamics
- Applied mathematics
- Process chemistry, polymer processing, petroleum engineering, and bioprocesses
- Process control and optimization
- Process simulation and modeling
- Reaction kinetics
- Transport phenomena

In ChEPS, computers and software packages are heavily used to supplement classroom lectures. Many courses offer hands-on workshops that demonstrate applications of the theories taught. As a result, ChEPS students are well-versed in many simulation programs and programming tools such as ASPEN PLUS™, PRO/II™, MATLAB™, LINDO™, and ControlStation™.

Industrial involvements are vital to the success of ChEPS. Sponsoring companies allow ChEPS faculty and students to access their production facilities, also known as practice stations, which play a pivotal role in providing practical training for students in the second year of their study. At the same time, sponsoring companies gain valuable human resources who can work on longer-term projects, thus freeing up company engineers to focus on more urgent needs. Consequently, maintaining this win-win partnership model between the university and the private sector hinges on the successful operation and implementation of practice stations.

The duration of the practice phase is five months. Students work in teams of two or three on two projects in series, and take turns being the project leader. So each project is 10 weeks long, during which there is a proposal presentation, a progress presentation, and a final presentation. ChEPS faculty members also travel to the site and attend these presentations to provide further input. Due to time constraints, most site projects tend to be simulation-oriented, which seek to debottleneck, troubleshoot, and optimize (e.g. minimizing energy consumption) existing plants. A few projects also involve feasibility studies and design of new processes. The practice team can be likened to a consulting team who are dedicated to solving problems for the host company. Ku *et al*. (2007) discussed the operation of a chemical engineering practice station in detail.

It should be stressed that the industrial internship in a practice school is not a cooperative education program (also known as co-op). The practice model and the co-op study are different in two important aspects. One is the presence of a full-time ChEPS faculty member, called a site director, who is dedicated to a practice station. The site director lives and works with student interns in housing provided by the sponsoring company. While company engineers identify and set the scope of the projects, the site director is responsible for ensuring the academic value of the proposed work, that the project goals are attainable, and that the work is carried out as planned. Furthermore, the site director provides technical advice, prepares students for presentations, and edits students' reports.

The second difference is the commitment of the host company at every level to the practice school, beginning with basic needs such as free housing accommodations, office space, computing facilities, and Internet access. Senior management is first approached, which sets a top-down policy on sponsoring ChEPS. Plant managers, engineers, shift operators, and technicians are also consulted, since they have to interact with the students. A team of engineers is then formed to work closely with students. In a nutshell, the practice school is more systematic and more organized, and is therefore far more efficient than the traditional co-op study.

Despite the similarities, the ChEPS curriculum is not an exact duplicate of the MIT model. Certain components were added to ChEPS to enhance the MIT model and compensate for common weaknesses in Thai students. For example, ChEPS introduced a course in engineering management to enable students to better manage time, people, and projects and gain a rudimentary understanding of corporate finance. Moreover, the program is lengthened to two academic years and one summer to accommodate the intense workload and schedule of the students. Additionally, ChEPS is supplemented with the following components:

- *Presentations*. Students hone their presentation skills by giving no fewer than 30 talks by the time they graduate. Presentations are required in every phase of ChEPS, including PBL problems, research thesis, and site projects.
- *A short research thesis*. Every student must pick a thesis project to be completed in six months. The extensive networking of ChEPS inside and outside KMUTT, including overseas institutions, allows students to choose just about any chemical engineering related topic that is of interest to them. In many cases, research projects are collaborated, which offers an opportunity for students to carry out part of their research outside Thailand, e.g. in Canada, the US, and Singapore. While ChEPS' primary goal is not to produce researchers, many students find the training useful. The students learn to think critically and analytically and must devise a systematic approach to solve a research problem. In fact, many ChEPS graduates have gone on to pursue Ph.D. degrees at other institutions, both in Thailand and overseas.
- *English tuition*. ChEPS requires that all students score at least 500 on the paper-based TOEFL (called PBT) or 650 on TOEIC by the end of their second year. This is a daunting task for most students. Hence, extra English courses are provided and students' progress is monitored closely. Students are required take either the TOEFL or TOEIC at least once a year. More recently, a mentoring system has been set up in which faculty members are responsible for a small group of students, helping them improve their writing, presentations, and English in general.

ChEPS is highly competitive and admits approximately 25 top-quality students from a pool of slightly more than 100 applicants from various universities in Thailand each year. For example, about two-thirds of ChEPS applicants have an undergraduate GPA of 3.0 or above in chemical engineering. As a result, the program has an elaborate admission process to ensure that only the best are admitted. A number of criteria including undergraduate GPAs, TOEFL English test, SAT Math test, and interview scores are used to screen the applicants. Each admission criterion is given a weighting factor, with GPA having the highest impact. Viravaidya *et al*. (2007) presented findings on the relative significance of admission criteria in the ChEPS program.

The success of ChEPS as a conduit for learning has been cited by Technology and Development Program (TDP) at MIT (2010), which works to build research and academic capacity around the world through its assistance in science and technology development. The program considered the KMUTT practice-school endeavor to be its success story in Thailand. At the same time, the practice school model is gaining traction among educators in Thailand, both in higher education and in vocational schools. The practice-based learning model originating from ChEPS at KMUTT has inspired the creation of many spin-off programs, both inside and outside the university, in the past 10 years. In addition to ChEPS, KMUTT now has five additional practice-based master's programs, namely the Food Engineering Practice School (FEPS), Starch Engineering and Process Optimization Program (SEPO), Bioinformatics (BIF), Biotechnology Practice School (BIPS), and Biotechnology Business Management Program (Bioentrepreneurship). Ku *et al*. (2005) gave a comprehensive review of the graduate-level science and engineering practice schools at KMUTT.

The FEPS program (Asavasanti *et al*., 2005) was established in 2001 to meet the demands for more food engineers, since Thailand derives a substantial amount of revenues from the exports of agricultural and food products each year and to adopt the Thai government's initiative to become the "kitchen of the world." While ChEPS students' background is exclusively chemical engineering, FEPS students have more varied backgrounds, including food science and technology, food engineering, and chemical engineering. The SEPO program was established in 2001 to develop human resources for the agro-industry, which is an important industrial sector in Thailand. SEPO students follow the standard curriculum of ChEPS or FEPS, except for six months in the second year in which they will be interned at a tapioca starch company. Their PBL projects also come from the starch industry. Site projects involve improving unit operations such as drying and hydro-cyclones and process optimization in the production of tapioca starch. The BIF program (2010) is a multi-disciplinary curriculum that combines the technical elements of computer science, biology, and biochemistry. Bioinformatics is the scientific and technical foundation of the human genome project, and promises to play a central role in life science of the coming century. BIF was established in 2003 as a joint program between the School of Bioresources and Technology and the School of Information Technology. Courses are taught jointly between the faculties of the two schools. Students in the program receive comprehensive training in genomics, algorithms for sequence analysis, database design and management, and software engineering and programming, including web-based development. Enrolled students have a background either in computer science or in biology with a few exceptions in engineering.

More recently, the School of Bioresources and Technology at KMUTT opened two practice-based master's of science curricula called Biotechnology Business Management and Biotechnology Practice School. These two curricula are multidisciplinary and innovative programs which aim to provide students with a multitude of knowledge in modern biotechnology and skills appropriate for wide career opportunities. The curricula were designed in response to rapid advances in genome science while a wide range of research projects serves the increasing demand of local biotechnology-related industries. Graduate students are trained in core biotechnology, such as molecular biotechnology, bioprocess engineering, environmental sciences, and business and legal aspects.

RUNNING THE PRACTICE SCHOOL

It is obvious that a practice-based program must provide a student-centric learning environment, and the old adage of "practice makes perfect" is an apt metaphor. Traditional lectures are still important in order to learn the fundamentals of chemical engineering, but ChEPS students learn more and learn faster when they practice what they have been taught. However, running a practice school also entails many challenges. One of them is the commitments in human and financial resources by both the university and industrial sponsors needed to make the collaboration work. For example, for a two-year curriculum such as ChEPS, which admits 20-25 students each year, 6-7 full-time equivalent faculty members and two administrative staff are needed to run the program effectively. In addition, a practice-based program requires complete dedication of its staff and special attention from the faculty. Moreover, for the program to be successful, a number of key factors must be put in place or implemented, ranging from the ability to recruit quality students, finding the necessary funding, integrating problem-based learning into classroom, to managing practice stations effectively.

Recruiting Students

The first lesson learned in running ChEPS is that recruiting top students into the program must be a priority. The old Chinese proverb "A journey of a thousand miles begins with one small step" is particularly apt when running a practice school. That "one small step" is the ability of the program to recruit quality undergraduate seniors from various chemical engineering departments around the country. It is crucial that the "raw materials" brought into a practice school, i.e. the students, be of top quality. Good students foster a culture of healthy competition within the program and serve as role models for others to emulate. With good engineering fundamentals, these top students often actualize their potentials which are brought upon by the intensity and challenges offered by the practice school. The result is the creation of well-rounded chemical engineers who are ready to serve the industry.

ChEPS accepts applications from undergraduate seniors enrolled in any university or institution in Thailand with a curriculum or department in chemical engineering. Basically, two ingredients must be put in place to attract good students. One is the availability of scholarships and financial support, which will be elaborated later. The other is the promotion of the program through "proactive recruitment". Unlike "passive recruitment" of many academic programs which wait for prospective students to apply, "proactive recruitment" targets students with "road shows" and on-campus presentations. The students will hear first-hand information from the program's staff instead of receiving the information through word of mouth and other indirect channels. In many cases, applications, already streamlined for simplicity, can be collected immediately after the presentation. At least 30% of ChEPS applications received each year are obtained this way.

Every year around November, about six months prior to the opening of a new ChEPS academic year, ChEPS will contact the chemical engineering department of a target university and request a "road show" presentation with its seniors. Generally, at least two staff or faculty members will do the road show together. The road show consists of a one-half hour slide presentation, followed by a 12-minute video presentation, and a "Question and Answer" session at the end. These presentations are often given in English to convey the international flavor of the program. In many cases, alumni of the target university who are currently enrolled in ChEPS also join the roadshow and talk to prospective students about their experiences in the program. These alumni are the program's best references.

Another added benefit of enrolling good students in the program is the attention they garner from corporate sponsors. Large chemical, petrochemical, and refinery companies see these top students as potential employees and are willing in certain years to provide full scholarships to some of the students while they study in ChEPS. In exchange, the students sign employment contracts which bind them to the sponsoring companies for a few years. This arrangement can be beneficial to all three parties. Sponsoring companies are able to sign up quality engineers earlier than their competitors, while the students are guaranteed employment upon their graduation from ChEPS. On the other hand, the scholarships provided by the sponsoring companies help alleviate the financial burden on ChEPS.

ChEPS' proactive recruitment can only be characterized as extremely successful. The program receives approximately 100 applications each year. The interest in the program remains strong even in the face of more competition from new graduate programs created in the past few years. Table 1 shows all the universities or institutions in Thailand with chemical engineering departments or curricula. Over the years, ChEPS has received applications from virtually every university displayed in Table 1.

Future Challenges in Recruitment and Solutions

In recent years, chemical engineering departments at many universities have grown more reluctant in arranging roadshow presentations for ChEPS for fear of losing their potential graduate students. Some departments are more concerned than others. Those located in the provinces with small or no graduate programs tend to welcome the ChEPS

Table 1. Universities in Thailand with chemical engineering departments

University/Institution	Abbreviation	Province
Burapha University	BU	Chonburi
Chiang Mai University	CMU	Chiang Mai
Chulalongkorn University (Chemical Engineering)	CU-ChE	Bangkok
Chulalongkorn University (Chemical Technology)	CU-ChemTech	Bangkok
Kasetsart University	KU	Bangkok
King Mongkut's Institute of Technology Ladkrabang	KMITL	Bangkok
King Mongkut's University of Technology North Bangkok	KMUTNB	Bangkok
King Mongkut's University of Technology Thonburi	KMUTT	Bangkok
Khon Kaen University	KKU	Khon Kaen
Mahidol University	MU	Bangkok
Prince of Songkla University	PSU	Songkla
Rajamangala University of Technology Thanyaburi	RMUTT	Bangkok
Silpakorn University	---	Bangkok
Srinakharinwirot Unviersity	SWU	Bangkok
Sranaree University of Technology	SUT	Nakhon Ratchasima
Thammasat University (Sirindhorn International Institute of Technology)	TU-SIIT	Bangkok
Thammasat Unviersity (Chemical Engineering)	TU-ChE	Bangkok

team. On the other end of the spectrum, a few departments will find every excuse to decline the request. In those cases, ChEPS needs to find innovative ways to circumvent the problem. One solution is to utilize its alumni to contact the seniors directly which allows ChEPS staff to correspond with the students. Departmental web boards are also a great way to advertise the program. Finally, some roadshow presentations can be arranged through personal contact with faculty members at target universities, e.g. asking their students to stay behind after class for a ChEPS presentation.

In the end, ChEPS alumni have become the program's best references as its number grows over the years. Having graduated 11 classes, ChEPS has produced a large pool of alumni base, now numbering 235 people. The majority of ChEPS alumni work for large refinery, chemical, and petrochemical companies. These alumni have become indispensable allies of ChEPS in spreading the good words about the program. In fact, many undergraduate seniors became interested in the program after hearing about ChEPS from alumni who often served as mentors or supervisors during these students' co-op study. Finally, seeing so many ChEPS alumni working in large companies by prospective students only serves to reinforce ChEPS' image and reputation as a unique program whose graduates are very much sought after by industries.

English Proficiency

ChEPS is highly competitive and admits approximately 25 students from a pool of about 100 applicants from various universities in Thailand each year. A number of admission criteria including undergraduate GPAs, paper-based TOEFL (PBT), SAT Math test, and interview scores are used to screen the applicants.

Any applicant with a PBT score below 400 (the full score is 667) is automatically eliminated from further consideration regardless of his or her GPA. It has been observed that there exists a strong correlation between the English proficiency of ChEPS students and their academic performance in the program. This is not totally surprising, since ChEPS is an international program and all lectures are delivered in English. Students with poor English skills tend to struggle academically and have problems absorbing what is taught. This is especially true with courses that are taught by English native speakers because students are not accustomed to the native accent and the speed of lecture. A fairly large number of students with excellent undergraduate academic records but poor English proficiency have turned out to be mediocre performers in ChEPS.

Recently, Buarod (2009) attempted to quantify the relationship between English proficiency of incoming students and their subsequent ChEPS GPAs. A linear regression was performed based on the PBT scores of students from Classes 4 -10 (total sample size = 150. PBT was not administered prior to Class 4). A moderately strong positive correlation was found to exist between the English proficiency and ChEPS GPAs with a Pearson's correlation coefficient of 0.331. The correlation is significant at the 0.01 level (one-tailed). The other two admission criteria, namely undergraduate GPA and SAT-Math, were found to be better predictors of the students' final ChEPS GPAs, but not by much ($r^2 = 0.448$ and 0.339, respectively). While the study could not conclusively show that English proficiency had a large impact on the students' ChEPS GPAs because other factors such as undergraduate GPAs were not taken into account, the evidence did support the observation.

Future Challenges in English Proficiency and Solutions

As much as ChEPS tries its best to admit students with good English skills (with all things being equal), most incoming students do not possess the rudiments capable of making a coherent oral English presentation and writing an error-free technical report or thesis. The average PBT score of incoming students is approximately 440. This is far below the acceptable level when one considers that most colleges in the US require international students to score above 600 on the PBT prior to admission. Consequently, ChEPS faculty spends a disproportionately large amount of time editing students' reports, correcting their presentation slides, and coaching them on how to present. This places a huge burden on the faculty. In the past, ChEPS had provided free English tutoring to small groups of students, hired the language department at KMUTT to teach extra English courses, and even subsidized students to enroll in outside English classes. The results are mixed and these initiatives have limited success. While the overall English skills of the students generally improved, they were still below the acceptable level.

There is no quick fix to the problem. The faculty will need to show patience and encourage all students to immerse themselves in English as much as possible. For their part, the students should show more initiative in mastering the English language. With the exception of one Canadian student from the University of Waterloo, all ChEPS students have been Thai. As a result, the classroom environment is not completely conducive to learning English. Despite all coursework and lectures being in English, the students still speak Thai among themselves. One solution is for the program to enroll some foreign students, particularly those from neighboring countries such as Cambodia, Laos, Malaysia, Singapore, and Vietnam. Students from other Asian countries such as China, India, Indonesia, and the Philippines are also good prospects. It can be argued that to be truly international, ChEPS must also be able to enlist foreign students in the program, thus fostering a learning milieu in which the spoken language is English. This endeavor is no simple task and will involve careful planning and going overseas to promote the program. It will certainly take many years before ChEPS is able to establish an international reputation.

First-Year Coursework and PBL

Although the uniqueness of ChEPS lies with the practical training in the second year, it is important that the quality of teaching and the content of coursework live up to the expectations of the students in the first year. First, there must be a distinct departure from the typical undergraduate style of teaching and learning in the ChEPS curriculum. While the former tends to emphasize breadth, i.e. cramming as many courses as possible into one semester, ChEPS courses focuses on depth and intensity. Weekly lecture hours are kept short, while homework and group projects abound. Students are to make regular oral presentations, and they improve their skills by practicing a lot and receiving feedback from the faculty.

Moreover, as an international program, the students also expect the courses to be taught by qualified lecturers, both locally and from overseas. A first impression makes a lasting impression. The last thing ChEPS needs is to see its students become demoralized during the first year, even before undergoing practical training, because the coursework is dull and the teaching is subpar. Sometimes, one or two less-than-ideal courses are enough to damage the goodwill and faith of the students.

The ChEPS faculty consists of both KMUTT and outside lecturers. Nearly 50% of the courses are taught by overseas professors from Singapore, Australia, and Canada, experts outside KMUTT, and ChEPS' industrial sponsors such as those from The Siam Cement Group (SCG) and Thai Oil Public Co., Ltd. (ThaiOil). At the closing of each course, students are asked to anonymously complete an online evaluation form to assess the quality of the course and its teaching. Table 2 shows the 12 courses in the first year of ChEPS, their core contents, and the instructors.

Another important aspect of the ChEPS curriculum which helps students prepare for their subsequent internships is the incorporation of problem-based learning (PBL) into some core

Table 2. Coursework in the first year of ChEPS

Course Name	Core Contents	Instructors
LNG601: English for International Program	English grammar and writing	KMUTT
CHE610: Fundamentals of Transport Phenonmena	Transport processes of momentum, heat, and mass	Outside
CHE641: Intermediate Chemical Engineering Thermodynamics	Applied thermodynamics such as physical property models	Outside
CHE642: Chemical Reaction Engineering	Advanced reactor design and kinetics	KMUTT
CHE643: Applied Process Chemistry	Organic and organo-metallic chemistry, petroleum processing	Overseas and Industry
CHE651: Mathematical Analysis for Chemical Engineering Practice	Mathematical analyses of chemical systems via ODEs and PDEs	KMUTT
CHE654: Simulation and Modeling	MATLAB and dynamics of chemical processes, PBL-integrated	KMUTT and Industry
CHE655: Fundamentals of Chemical Engineering Practice	Plant design projects and group presentations, PBL-integrated	None
CHE656: Computer Applications for Chemical Engineering Pracice	Simulation of chemical processes with ASPEN PLUS	KMUTT
CHE657: Design Problems in Chemical Engineering Practice	Industrial projects and oral presentations, PBL-integrated	KMUTT and Industry
CHE658: Systems Engineering	Process control and process optimization	Overseas
CHE670: Engineering Management	Project management, financial analysis, marketing, and planning	Industry

courses during the first year. PBL is vital in helping students hone their problem-solving and presentation skills. In most cases, these case studies, which tend to be too narrow in scope to be site projects, are solicited from sponsoring companies. The PBL projects introduced into the classroom mimics certain aspects of the site projects. The similarities are:

- Students work in teams of three or four people.
- Typical projects involve modeling, simulation, and optimization of chemical processes or systems.
- Regular oral presentations are scheduled to keep the faculty abreast of the latest progress.

There are a number of ways for ChEPS to solicit PBL projects. One is through its site directors. Sponsoring companies such as ThaiOil, SCG subsidiaries, and PTT Chemical Public Co., Ltd. (PTT-Chem) often propose several potential site projects at a time. Some of these site proposals, if not selected as site projects, could be given to the first-year students as PBL projects (also known as design problems). All of these require careful planning, coordination, and many meetings, usually many months in advance, before the PBL projects are ready to begin.

Despite the similarities, one major difference between PBL and site projects is that, after an initial briefing by the sponsors, their involvement is kept to a minimum so as not to disrupt their routine work schedule. Instead, a ChEPS faculty member is assigned to provide technical advice on a regular basis. Students are encouraged to use only emails to contact the sponsors for further input and clarifications. On the other hand, sponsors usually ask for one progress presentation. After eight weeks, a final presentation is held at the

Table 3. Companies sponsoring ChEPS' PBL projects

PBL Sponsoring Company	Abbreviation
Alliance Refining Co., Ltd.	ARC
PTT Chemical Public Co., Ltd.	PTT-Chem
Rayong Olefins Co., Ltd.	ROC
Thai Lube Base Public Co., Ltd.	TLB
Thai Oil Public Co., Ltd.	TOP
Thai Plastic and Chemicals Public Co., Ltd.	TPC
Thai Polyethylene Co., Ltd.	TPE
The Aromatics (Thailand) Public Co., Ltd.*	ATC

*Now called PTT Aromatics and Refining Public Co., Ltd. (PTTAR)

sponsoring company, by which time it will also receive a copy of the final report.

At present, PBL is integrated into one course in each academic term. In the summer, groups of students work on plant design projects as if they were employed by an engineering firm. In the first semester, PBL is incorporated into a modeling/simulation course which teaches MATLAB and dynamics of chemical processes. In the second semester, PBL is part of an optimization course which is a crucial element in process engineering. In all cases, oral presentations and written reports are compulsory. The students are also critiqued on their presentation skills.

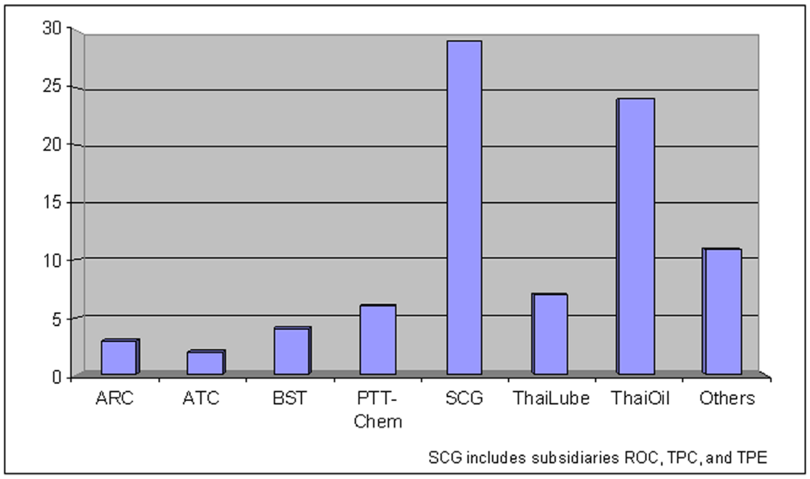
The use of PBL is a great way for ChEPS to network with industries. In fact, not all case studies in PBL come from companies that serve as practice stations. In many cases, ChEPS is able to solicit projects from other companies through its alumni who work there. In addition, some companies are interested in sponsoring PBL because of the possibility of their becoming future practice stations. To these companies, sponsoring PBL is an ideal way to test-drive ChEPS and its practice model before more substantial resources are committed. Table 3 shows past contributors to ChEPS' PBL projects and Figure 3 shows the number of PBL problems sponsored by each company.

Future Challenges in Coursework and Solutions

ChEPS students are by and large very happy with the coursework. This was not always the case, especially in the early years of the program. A lot of efforts have gone into finding the appropriate people to teach the courses and making certain that all the courses follow the same or similar format. Grading must be kept fair and objective. One feature of ChEPS classes is that they tend not to follow a fixed timetable. In fact, many classes are taught on weekends and many courses are crammed into just a few weeks in order to accommodate the busy schedule of overseas lecturers and instructors from industry. This sometimes poses a bit of a challenge to the ChEPS administrative staff in reserving classrooms and confirming all classes. Furthermore, students tend to suffer from more stress during these busy block courses. However, the benefits of having a diverse and qualified teaching body in the program far outweigh the minor inconveniences. In fact, block courses can help prepare ChEPS graduates for the real world, since the ability of professional engineers to absorb a large amount of materials in a short time is an important skill. Most subsequent courses in professional development are run in this manner.

On the other hand, implementing PBL in a course is extremely time-consuming and has yielded mixed results. An ideal PBL project should be sponsored by a company, is well-defined, and is supported by fairly complete plant data. In reality, it is difficult to solicit enough PBL projects from the industry. It is even more difficult to find projects that meet all of the three stated criteria. Even when such a problem exists, the efforts and time needed to implement PBL can be enormous. Students must work closely with their KMUTT advisors and the sponsors, since the problem can be open-ended with no single correct answer. One constant challenge is finding well-defined design problems that are supported by reliable plant data. When the input information in a design problem is

Figure 3. ChEPS PBL projects sponsored by companies



incomplete, assumptions need to be made which render the solutions less meaningful. Another challenge is the commitments of the sponsoring engineers of PBL, who are usually tied up with their routine work and have little time to interact with the students. Finally, because the nature of the design problems is very varied and spans the full spectrum of the chemical engineering fields, finding the faculty with the appropriate expertise to advise the students is not easy.

Whenever ChEPS runs into a dearth of design problems, the workaround is to substitute one with a problem from the literature. While this is less than ideal because of the problem's academic nature, the students at least have an opportunity to work as a team on a problem which is well-defined. In conclusion, ChEPS students generally find the integration of PBL projects into their core courses useful but are sometimes frustrated by some of the obstacles, which are actually important for their learning.

Financial Support and Scholarships

There are many graduate chemical engineering programs in Thailand, some of which have even longer history than ChEPS. The competition for quality students is therefore fierce, and has recently intensified as more programs are offered. Scholarships and financial support in the form of monthly stipends are needed in order to attract good students, as those with outstanding GPAs do not expect to pay for their graduate studies. As a result, ChEPS needs to secure financial resources to afford these scholarships.

ChEPS offers scholarships and monthly stipends to qualified candidates. The financial support comes from numerous sources, including funding agencies, sponsoring companies, donations, and loan payback from alumni. The funding agencies are:

- Energy Policy and Planning Office (EPPO), formerly National Energy Policy Office (NEPO)
- National Science and Technology Development Agency (NSTDA)
- Petroleum Institute of Thailand (PTIT)
- The Suksapattana Foundation

The mission of EPPO under the Ministry of Energy is to foster energy conservation and promote public awareness regarding energy savings. Since ChEPS engineers often help the industry to save money by minimizing energy consumption, EPPO has a direct interest in funding the program. NSTDA is a public organization whose mission is to advance and sustain the economic development of Thailand through research, technology development, and the promotion of collaboration between the public and the private sectors. PTIT is an independent non-profit organization supported by the government, academic and private sectors. PTIT's members comprise of petroleum and petrochemical companies, and the institute's main mission is to assist with the development of the two industries in Thailand in areas of human resource development, information service, policy and regulatory issues. Finally, the Suksapattana Foundation is a non-profit organization dedicated to the development of education and innovation in learning.

Companies who have contributed resources, both in-kind and cash, to ChEPS include:

- BST Elastomers Co., Ltd.
- ExxonMobil Exploration and Production Khorat Inc.
- ExxonMobil Limited
- PTT Aromatics and Refining Public Co., Ltd.
- PTT Chemical Public Co., Ltd.
- PTT Group and PTT Research and Technology Institute
- Thai Lube Base Public Co., Ltd.
- Thai Oil Public Co., Ltd.
- The Siam Cement Group and its subsidiaries

More recently, the Thai government channeled a substantial amount of money to support all practice-based programs in the country via NSTDA, which initiated the University-Industry Research Collaboration Program (U-IRC). The objective is to encourage more collaborative research between the universities and industries, which will improve corporate Research and Development and help enhance their competitiveness. KMUTT was the largest recipient of this funding.

ChEPS in turn offers three types of scholarships to students: full scholarship, half scholarship, and soft-loan. Under no circumstances are students required to pay while they study in ChEPS. Those who are not qualified for full scholarships are offered no-interest soft loans, which are to be paid back each month amounting to 10% of their salaries once they start working. Full scholarships are unconditional, while half-scholarship recipients must pay back the other half given out as loans. Together, full and half scholarship recipients account for about one-half of the students. The soft-loan with 0% interest has been one of the attractive selling points of ChEPS, enabling needy students to be admitted into the program without having to take a private loan.

Future Challenges in Funding and Solutions

It is not realistic to expect the funding agencies and the government to finance ChEPS indefinitely. For example, the U-IRC program is only good for two years or one class of students, and its future funding appears uncertain. Sooner or later, all practice schools must demonstrate their ability to sustain themselves financially. For future financial resources, ChEPS will need to rely on subsidies from KMUTT, financial contributions from its alumni, and more grants from industries. For that to happen requires a larger alumni base and the willingness of industrial sponsors to invest in higher education. At present, ChEPS continues to receive payback from its alumni who were on soft-loan and half-scholarships. While this payback represents a relatively small percentage of ChEPS' total annual operating budget, the amount is expected to grow substantially as more students graduate each year and join the workforce. It is projected that in a few more years, the alumni fund will grow sufficiently large to cover 50% of the budget.

One problem facing the program, especially in the early years, is the soft-loan payback from the alumni. Because the soft-loan agreements between ChEPS and students are not contracts and therefore are not legally binding, many students were unscrupulous in their payments. The payments were often intermittent or late. Fortunately, ChEPS maintains a database that tracks employment records and personal information, such as home addresses, email addresses, and mobile numbers, of its alumni. So the program has a good idea of the whereabouts and job functions of its alumni. The database is useful in sending out friendly reminders about overdue loan payments. Moreover, many ChEPS alumni end up working for the program's industrial sponsors who have good working relationships with ChEPS. Usually, a more aggressive reminder by email or letter is enough to convince most alumni to fulfill their obligations. A future ChEPS alumni association is desirable and would prove useful as a networking forum among the alumni, the program, and the industrial sponsors.

ChEPS has in the past asked and continues to ask all industrial sponsors to contribute more financially to the program, particularly in the form of scholarships and service fees for site projects. Having been shown the positive impact of practice school on industries, these companies are generally willing to shoulder some of the financial burden with some scholarships, housing accommodations, student allowances, and other in-kind contributions. However, while the sponsoring companies agree that the practice school benefits them, they do not think they should bear the financial burden alone. First is the issue of how to accurately quantify the savings to the companies after site projects have been completed. Second is the prevailing thinking that the cost of educating graduate students should partially lie with the government, the university, or even the students themselves. Thailand does not have a tradition of big endowments on higher education by the private sector. Furthermore, industrial sponsors of ChEPS tend to be big public companies which are constrained by their boards of directors, shareholders, and highly regulated policies. Consequently, securing substantial endowments from these companies has always been a challenge.

ChEPS will continue to convince companies to see the importance of funding higher education and the values of the site projects. It is now customary for ChEPS interns to calculate and attach a cost saving or profit increase to every site project. The purpose is to demonstrate to the sponsoring companies about the values of research and its potential benefits to the companies' bottom lines, which hopefully will encourage them to invest more financially in ChEPS. As more petrochemical and refinery companies embark on developing their own in-house Research and Development, it becomes obvious that the required human resources, know-how, and knowledge must come from universities. It is hoped that these companies will eventually develop a tradition of supporting universities throughout the country with more endowments.

In the end, for long-term sustainability a practice school should be run more akin to a business joint venture. As in any business model, there are stakeholders. In the practice school, the three stakeholders, namely the university, the student, and the industry, should contribute and share the cost of running the practice school since they are the primary beneficiaries. To a certain extent, this business model is working well at KMUTT, at least in the short term. However, more needs to be done to integrate all practice-based curricula at KMUTT into one practice school with shared resources and to convince all stakeholders to sustain the school over the long term.

Operating Practice Stations

For the practice school to be successful, a sponsoring company must be completely committed to the partnership. This means that the company's staff at all levels must be brought in early in the decision-making process, beginning with the managing director, plant managers, engineers, all the way down to technicians and shift operators. The company's management sets the policy and allocates the necessary resources to run the practice station. But it is the engineers and operators with whom the students have to work daily. In other words, everyone in the company must be a firm believer of the practice school model and is totally committed to making it work.

Initially, the partnership between ChEPS and the companies are officially cemented through the signing of a memorandum of understanding (MOU) or a contract. The agreement clearly spells out responsibilities of each party, expectations from each side, details about financial obligations, and issues regarding safety and ownership of intellectual property. For example, it is a standard practice for companies to offer in-kind contributions, such as office facilities, computers, and administrative support, and pay for housing of the practice team. In some instances, the companies pay monthly stipends to the students. In the past, ChEPS has been able to charge some companies consulting fees on the per-project basis as well. In any case, each practice station is somewhat different. There is no fixed formula on cost sharing, which is dealt with on a case-by-case basis.

What distinguishes a practice school from a regular co-operative program is the presence of a full-time site director at a practice station. The site director is a faculty member with a PhD degree who runs a practice station. In the first few years of ChEPS, the site directors received their training through mentoring and working closely with their counterparts at MIT's practice stations in the US for six months. In subsequent years, new site directors were trained in a similar fashion by spending a few months at ChEPS practice stations. At present, there are two full-time site directors in ChEPS who supervise 20-25 students at various practice stations.

The site director lives and works with student interns in housing provided by the sponsoring company. While company engineers identify and set the scope of the projects, the site director is responsible for ensuring the academic value of the proposed work, that the project goals are attainable, and that the work is carried out as planned. Furthermore, the site director provides technical advice, prepares students for presentations, and edits students' reports.

The site director has the following specific responsibilities:

- *Identify projects*: The site director must work closely with the industrial sponsors at the outset to identify potential site problems. Here, the site director's main job is to screen the proposed projects and to ensure that the ones chosen contain academic values. For example, asking students to survey existing tray types because the company wants to design a new distillation column may be of interest to the sponsors, but the project offers little technical value from which the students can learn.
- *Prepare a working timetable*: The site director is responsible for forming student groups and planning a work schedule that includes all the presentations.
- *Provide technical advice*: While the students rely on company sponsors for their technical expertise and advice, the site director should be able to advise students on the more general technical issues. The frequent meetings allow company engineers and the site director to exchange ideas and learn from each other.
- *Review and edit reports*: The site director is expected to spend a great deal of time reading and editing students' reports. Since all written documents are in English which is not ChEPS students' native language, the site director must also edit grammar and diction in all reports. Moreover, the site director ensures that all oral presentations go smoothly by reviewing students'

presentation slides and listening to their rehearsals.

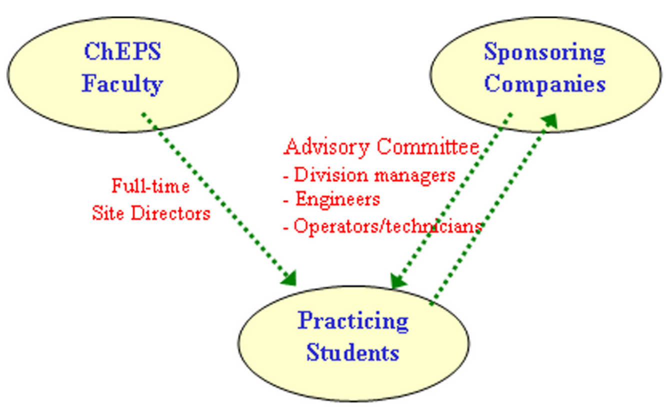
Because of their close proximity, site directors have more access and more opportunities to see the sponsors. Although not their main job function, it is customary for site directors to elicit research topics from the sponsors as ChEPS theses to be carried out in the second year. These individual research problems, which tend to be too big to be site projects, may be advised by any faculty in ChEPS including site directors. This joint research adds another dimension to the collaboration between the practice program and the company.

A few weeks before practical training is to begin, the sponsoring company will form an advisory committee, typically consisting of division heads, engineers, and plant operators. The site director will then meet with this committee to identify projects and produce a detailed work plan. The duration of the practice phase is five months (one semester). Students work in teams of two or three on two projects in series (two phases), and take turns being the project leader. As a result, each project is ten weeks long, during which there is one proposal, one progress, and one final presentation. Figure 4 shows the working dynamics among the ChEPS faculty, the sponsoring companies, and the practicing students.

The operating procedure of site projects is outlined below:

- *Problem Assignment:* The problem statement will provide students with background, motivations, and a list of objectives for the project. In addition, names of company employees who might be of help to the students are given. Also included in this document are possible solution methods and issues to consider which will help the students get started.
- *Project Planning and Organization:* Since time is of essence in solving a site project, students must place special emphasis on planning and organizing the project. The first logical step is to investigate thoroughly the background of the given problem. Specific objectives of the project are then defined, followed by the scope of work and a systemic solution approach. It is interesting to note that information feedback is a vital part of this process, i.e. the initial plan of actions must be continually reviewed in light of the most current results.
- *Sponsors Meeting:* A meeting with station sponsors will take place one or two days after the problems have been assigned. This meeting is crucial and requires good preparation to ensure the students get a strong

Figure 4. Working relations in a practice school



start on their projects. The group leader is expected to run that meeting. Progress meetings may be scheduled if such need arises, e.g. when students run into serious obstacles or need to air major complaints.

- *Investigative Memorandum (IM):* All student groups are required to write a brief description of the problems and their solution methodology during the week after the problems have been assigned. Safety is an important part of the IM, and special attention is given to sections on operational procedures and hazards of materials. The site director will review the first draft of the IM. Company sponsors will then comment on the document. An IM contains the following sections:
  1. Background
  2. Objective(s)
  3. Method of Approach
  4. Safety
  5. Hazards of Materials
  6. References
  7. Work Schedule
- *Proposal Conference:* Shortly after the IM has been submitted, students will schedule a proposal presentation with the sponsors, in which objectives and a detailed solution methodology will be presented. This is an important forum for sponsors to ask tough questions and critique the proposed work. By this time, the students should have familiarized themselves with the appropriate theories, previous experimental work if any, and other relevant technical information.
- *Progress Report:* Each project will have a mid-phase oral presentation in which the students update the company with the general status of their work, including what is planned.
- *Final Report:* The final oral presentation and report complete the engineering work. The final report should clearly state the conclusions and recommendations. The body and appendices of the report should also include sufficient technical materials and data for other engineers to duplicate or verify the students' findings.

The following is a list of past and present practice stations in the ChEPS program. Except for ThaiOil and ExxonMobil which are located in the Sri-racha Province (about 150 kilometers southeast of Bangkok), the remaining companies are all located in the Mathaphut Industrial Estate in the Rayong Province (about 180 kilometers southeast of Bangkok).

Future Challenges in Operating Practice Stations and Solutions

The cooperation and support that ChEPS receives from the sponsoring companies at all levels have been exceptional. In nearly all cases, ChEPS site directors and students have excellent working relationships with the engineers and operators. ChEPS is not aware of any major conflicts between the two parties that could have jeopardized the site projects. However, the operators and even engineers may occasionally feel slighted when the final presentations given by ChEPS students were well attended by the top management. In those cases, a joint presentation given by both the ChEPS students and the company's working team should be considered.

At the same time, site directors play a vital role in the success of ChEPS. They are the "eyes and ears" of the program who interact directly with the practicing students and the sponsors. Not only do they need to possess the necessary technical skills, preferably in process engineering, simulation, and optimization, they must also have good people skills and a good command of the English language. On the other hand, not all ChEPS site directors are well-versed in process engineering and simulation. Moreover, convincing the faculty to become site directors is not easy, as

Table 4. Past and Present Practice Stations of ChEPS

Company Served as a Practice Station	Service Period
Aromatics (Thailand) Public Co., Ltd. (The)	2002-2005, 2007
BST ELastomers Co., Ltd.	2001-2002
Exxon Mobil Limited	2007
PTT Chemical Public Co., Ltd.	2008-Present
Rayong OlefinsCo., Ltd.	2002-Present
Thai Oil Public Co., Ltd.	1998-Present
Thai Polyethylene Co., Ltd.	1998-1999, 2001, 2007-Present
Siam Mitsui PTA Co., Ltd.	2003, 2007-Present

most of them prefer to focus on their research on campus and are reluctant to re-locate to provinces. Monetary compensation and the chance to network with industries are the key incentives. Also, it was found that younger and new faculty staff are more likely to agree to move to the site because of the need for industrial exposure and their propensity to try new things. One reason ChEPS has been unable to expand its class size beyond 30 students each year despite strong interest in the program is a lack of qualified site directors.

ChEPS and industrial sponsors do not wish to see a separation between site and campus activities, which arises naturally because of the long physical separation between practice stations and the KMUTT campus. Sponsors value the input and participations of people from campus with site activities. In some site projects, the site director does not have all the expertise to advise the students. Instead, the faculty on campus may be able to offer new perspectives or better insights into solving a problem. Every time there is a presentation at a practice station, ChEPS does its best to send at least one faculty member from KMUTT to attend. Sometimes first-year students are asked to accompany this faculty member so they can see first-hand the activities at the sites. Because the presentation forums occur fairly frequently at practice stations, finding someone to travel to the sites each time can be difficult. Moreover, the expense in terms of time and money in transporting ChEPS faculty to the remote practice sites to attend the presentations is significant. Since ChEPS often has at least two site directors working concurrently at two different locations that are in close proximity, one site director is sometimes asked to cover the presentations of another site director. That helps reduce the number of trips between the campus and the practice stations.

Another issue that ChEPS must contend with is the fact that because all of ChEPS' practical stations are large refinery and petrochemical complexes, only a small section of the plants can be studied at a time. Moreover, companies are reluctant to divulge any confidential data or information, particularly those pertaining to costs, prices, or savings. Thus, it is not easy to put the value of a site project in monetary terms, although ChEPS strongly encourages the students and the industrial sponsors to include economic evaluation as part of each site project. The aim is to quantify and put a dollar figure on the success of each project.

ChEPS has complete confidence that site projects are valuable to the sponsoring companies. Some companies such as ThaiOil have openly stated that ChEPS students have over the years helped the company save millions of dollars in costs and energy consumptions. However, there is little ChEPS can do if a sponsoring company is not willing to share more precise figures or reveal how much an impact a project has on its bottom line. At the same time, it must be admitted that not all site projects are of high-impact or high-value in nature. Even in cases where the savings can be quantified, they are simply potential savings unless the recommendations are implemented. Consequently, as much as ChEPS tries to glean financial information from its sponsors with questionnaire and personal interview, it is extremely difficult for the program to assess the impact of site projects in monetary terms.

Thesis Projects and Overseas Collaboration

The ChEPS curriculum requires that all students undertake a short research thesis (6 credit hours as opposed to the regular 12 credit hours) for six months in the second year. This component is missing in the MIT's practice school. ChEPS feels that the inclusion of a thesis in its curriculum adds another dimension towards improving students' critical and analytical thinking. This training is particularly vital to any ChEPS students who wish to pursue doctorate degrees. Research topics in ChEPS span just about any field in chemical engineering, such as process simulation and optimization, fuel cells, catalysis, environmental engineering and clean technology, biomolecular engineering, biotechnology, waste engineering, energy, polymers, and membranes. These thesis projects are mainly supervised by faculty within the chemical engineering department, although a few are collaborated with or supervised by people outside the department or the university.

When ChEPS was first envisioned, there was little emphasis on collaborative research with overseas institutions. As the year progressed, it turned out that the opportunity to conduct research overseas was the main incentive in attracting students to enroll in the program. One of ChEPS main competitors in Thailand has overseas academic partners and allows some of their students to carry out their research overseas. This has been a strong selling point of that program. When recruiting students, ChEPS is often asked about the opportunities for overseas research.

In recent years, about one quarter of ChEPS students carry out their research during the second year outside Thailand. The students typically spend 4 - 5 months conducting research under the supervision of ChEPS overseas partners. Since all of the faculty members in ChEPS have doctorate degrees from overseas institutions, mostly from North America, the program has an extensive network of overseas connections. Moreover, academicians tend to be open to collaborative research. As a result, it is not difficult to find overseas academic collaborators who are willing to take ChEPS students. Table 5 shows past and present overseas research partners of the ChEPS program.

Future Challenges in Overseas Collaboration and Solutions

Every ChEPS research thesis is required to have a KMUTT advisor. However, because overseas research topics usually originate from ChEPS' counterpart, it is often difficult to find an advisor at KMUTT or in ChEPS who is specialized in the same field. This could sometimes be problematic when the students have no expert to advise them prior to defending their research proposals and going overseas. Furthermore, once the students go abroad, it is difficult to keep track of their progress which could jeopardize the chance of their completing the thesis in 5 months. One solution is to require that all overseas students submit bi-monthly progress reports of their research to their KMUTT advisors.

Another potential problem with overseas collaboration is to ensure that the research projects are well-defined and that their scopes are sufficiently narrow to be completed in 4 - 5 months. The standard procedure is for ChEPS to first screen the projects scrutinizing their scopes and methodologies, find co-advisors within KMUTT

Table 5. Past and present overseas research partners of ChEPS

Overseas Research Partners	Location
Carnegie-Mellon University	Pennsylvania, USA
Clemson University	South Carolina, USA
EnerDel, Inc.	Indiana, USA
James Cook University	Townsville, Australia
National University of Singapore	Singapore
University of South Florida	Florida, USA
University of Toronto	Toronto, Canada
University of Waterloo	Waterloo, Canada

who have the appropriate expertise in the proposed fields, and match the projects with ChEPS students who have interest in the fields. On the other hand, an individual research project often represents the first time a student is to conduct research independently. The student must be capable of understanding technical papers and assimilating new ideas with little supervision. The time constraint and the alien environment in overseas collaboration pose unprecedented challenges to the student, not to mention the language barrier. However, when this arrangement works well, the student benefits tremendously from the overseas experience, including a chance to interact with other international graduate students, work closely with experts in the research field, and improve her English proficiency.

At present, the overseas research collaboration seems too haphazard. The reason is that there is no official agreement between KMUTT and the overseas partners, either at the university level, the faculty level, or even the departmental level. Instead, all collaborations have been based on personal contact and connections. Consequently, it is difficult for ChEPS to match the needs of the students with those of the overseas institutions. For example, in certain years there could be a surplus of overseas projects, while in other years, many people vie for only a few available projects. If more students continue to show a strong interest in overseas research, the collaboration should be made more formal via MOU agreements between KMUTT and overseas institutions.

Program Output and Evaluations

The success of ChEPS can be judged on many levels. One is the academic records of the admitted students. Table 6 shows the distribution of universities and the average GPA of admitted students from Class 1 to Class 14. The table shows that ChEPS students are well represented by every university in Thailand that has a chemical engineering department, and that the caliber of the students applying to and admitted into ChEPS has been exceptional. Academically, admitted students are typically ranked in the top 15% of their respective classes with an average GPA of 3.20.

An objective assessment of site projects after their completion is also crucial and is an integral part of the practice school used to judge the success of the program. This documentation helps students identify their areas of weakness. At the same time, sponsors also use this evaluation to document the impact of the students' work and convey the findings to the senior management, who will decide if follow-up studies or implementations of the proposed ideas are warranted. Moreover, some financial supporters of ChEPS requires that the program submit the findings, often in the form of short abstracts, to demonstrate how their funding benefits the chemical and pet-

Table 6. Academic profile of admitted ChEPS Students, Classes 1 - 14

University	No. of Students	Avg. GPA
Burapha University	5	3.05
Chiangmai University	11	3.33
Chulalongkorn University (Chemical Technology)	16	3.19
Chulalongkorn University (Chemical Engineering)	24	3.14
Kasetsart University	42	3.15
King Mongkut's Institute of Technology Ladkrabang	39	3.20
King Mongkut's University of Technology North Bangkok	19	3.16
King Mongkut's Universityof Technology Thonburi	98	3.25
Khon Kaen University	1	3.17
Mahidol University	13	3.13
Prince of Songkla University	4	3.37
Silpakorn University	1	2.90
Srinakharinwirot University	1	3.45
Suranaree University of Technology	1	3.09
Thammasart University	19	3.19
University of Waterloo	1	Excellent Stand.
Total	295	3.20

rochemical industries, e.g. in reducing energy consumptions or boosting the industries' competitiveness.

The assessment of site projects is divided into two parts. The first is the evaluation of the students' performance by the site director alone. Site directors then work closely with the sponsors in the second part to evaluate the overall success of the projects, including the amount of money the company can save if recommendations in the study are implemented. Further calculations may be needed here, since not every project will contain cost-saving analyses. It should be noted that ChEPS is not privy to this information; as such data are considered confidential by the company. Typically, the students are judged in the following four broad categories:

- Problem-solving approach
- Accuracy and completeness of work
- Presentation skills
- Command of the English language including final reports

There are five numerical ratings in each category with 5 being the best. Some site directors prefer to conduct a student evaluation right after the presentation, in which each student presenter is critiqued by her peers. Figure 5 shows the performance evaluation form used by ChEPS for site projects.

Another indicator that can be used to gauge the success of the ChEPS program is the track record of employment of its alumni. Figure 6 shows the employment profile, categorized by industrial sectors, of ChEPS alumni based on 235 students from 11 classes. About half of the graduates currently work for large chemical, petrochemical, and refinery companies. A sizable number also work for small-to-medium enterprises (SMEs), e.g. those in the sugar and food industries. Finally, about one-tenth of ChEPS

Figure 5. ChEPS performance evaluation form for site projects

KING MONGKUT'S UNIVERSITY OF TECHNOLOGY, THONBURI

Chemical Engineering Practice School (ChEPS)

Performance Evaluation Sheet

Project: ____________________

Student Names: ____________________ Phase: ______ Semester: _______

Overall Evaluation:

Major Strengths

Areas for Improvement

	Needs improvement	Outstanding		Needs improvement	Outstanding
	1 2 3	4 5		1 2 3	4 5
Engineering Skills			Organization skills		
Quality of technical work			Communication:		
Creativity			Oral		
Leadership			Technical writing		
Dependability			Personal		
Motivation			Engineering judgment		
Sense of responsibility			Ability to make decisions		
Response to technical guidance			Ability to work under pressure		

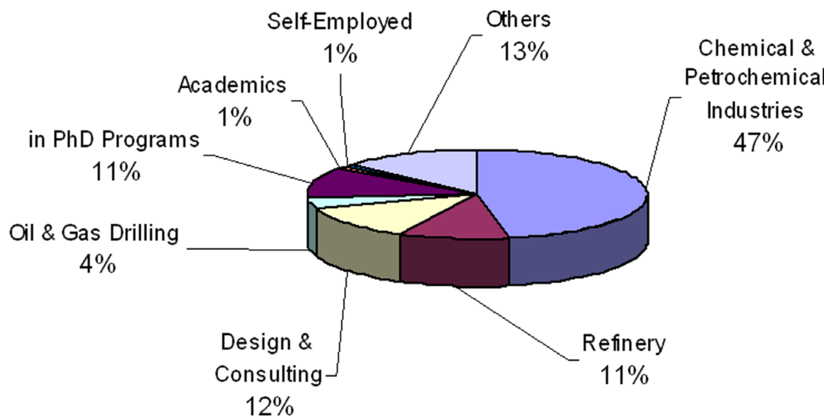
Name and Signature of Evaluator: ____________________ Date: ______________

alumni has become affiliated with universities or pursued PhD degrees.

As a financial supporter of ChEPS, NSTDA in 2002 appointed Chulalongkorn University Intellectual Property Institute (CUIPI) to conduct an independent audit of ChEPS and evaluate the outcomes of its collaboration with industry. At the time, ChEPS had been running for five years, and there was considerable interest from all stakeholders including KMUTT to know if the program was on the right track. CUIPI set up a working team, who visited KMUTT, interviewed ChEPS students and alumni, talked to industrial sponsors, and reviewed important documents in the program. CUIPI scrutinized four aspects of ChEPS, namely financials, external administration, internal administration, and knowledge management. Each aspect was further divided into sub-categories, which were rated against benchmark numbers. The study concluded that in most cases ChEPS was able to meet or exceed the target numbers. The only weakness was in the knowledge management where the students failed to benefit sufficiently from the short research in the curriculum. The study put the blame on the time constraint and the limited scope of research, which resulted in few conference papers and publications.

Finally, ChEPS also conducts periodic surveys with site companies and employers of ChEPS graduates, although these surveys tend to be

Figure 6. ChEPS graduates employment profile, Classes 1 - 11



informal. The feedback so far has been positive, and preliminary data show that companies are generally happy with the performance of ChEPS graduates. The strengths of the ChEPS graduates often cited are good English proficiency, good presentation skills, self-confidence, and a short learning curve. The fact that most sponsoring companies continue to make their sites available is a testimony to the benefits and values of the practice school.

Future Challenges in Program Evaluations and Solutions

It is obvious that based on several criteria, such as the academic credentials of incoming students, their subsequent employment record, and the feedback from the employers, the ChEPS program can be regarded as successful. When a large company looks to hire a chemical engineer with a master's degree, ChEPS graduates tend to be strong candidates. In addition, if ChEPS alumni were treated as customers, their level of satisfaction would be ranked very high. To date, very few alumni regret enrolling in ChEPS. The majority only have good things to say about the program.

On the other hand, much of ChEPS output has not been quantified or has not been done so for a long time, thus making it hard to evaluate the program objectively. The core issues are the impact of site projects on the sponsoring companies' bottom line and the extent at which the program meets the students' expectations in terms of skills and knowledge acquisition. It has been almost 10 years since ChEPS was last evaluated. Another systematic and comprehensive study should be carried out in the near future to assess the academic rigor of ChEPS and determine the impact of the program on the chemical, petrochemical, and refinery industries in Thailand.

After more than a decade in operation, the ChEPS curriculum remains largely the same. Work is currently underway to revamp the curriculum to reflect the changing needs. For example, applied thermodynamics will be emphasized in the Intermediate Thermodynamics course. Process Control and Process Optimization in the Systems Engineering course will be split into two smaller courses, since the two subjects are quite different and involve two different instructors. Other soft-skill developments such as mind-mapping and Lego Mindstorms workshops will also be introduced into ChEPS as part of the students' orientation. Awareness of self, others, and the environment, e.g. social and ethical responsibilities, should also be an important part of the students' engineering education. Community services such as visiting orphanages and building houses for the homeless and needy will be included in the students' schedule. Finally, to strengthen the focus and bring peace of mind to the students before being immersed in the intensity of the curriculum, an extended meditation trip to a temple in the province will be organized. Some of these initiatives were implemented in the past, but the activities were too few and far between and were never implemented as parts of students' routine.

FUTURE RESEARCH DIRECTIONS

The success of the practice-based learning model originating from ChEPS at KMUTT has created and inspired many spin-off programs both inside and outside the university in the past 10 years. In addition to ChEPS, practice-based curricula in food engineering, bioinformatics, biotechnology, and biotechnology business management were subsequently opened at KMUTT. Moreover, a number of engineering departments outside KMUTT in Thailand have also introduced industrial projects into their curricula, although none of them were as organized and on the same scale as ChEPS and those at KMUTT.

Starting in 2005, ChEPS also expanded its program to include a PhD component, called PhD-ChEPS. The objective is to link academically outstanding students with companies who are developing in-house R&D. Qualified PhD candidates would enroll in the Department of Chemical Engineering at KMUTT, but are sponsored financially by host companies and work on research topics originating from them. In some cases, the PhD students are also co-supported by The Royal Golden Jubilee Ph.D. Program (RGJPhD) provided by the Thailand Research Fund (TRF). TRF is a juristic body that is technically a part of the government system but operates outside the government administrative bureaucracy for the sake of efficiency. The mission of TRF is to foster basic research and technology development at the graduate level and address the severe shortage of highly qualified human resources in science and technology in Thailand. Some funding in the the RGJPhD Program explicitly requires that the PhD projects be collaborated with industry. So far, PhD-ChEPS has started small and admits only 1 or 2 students each year because of the rather stringent constraints. The SCG and the PTT Group are the two corporate sponsors.

In the private sector, the SCG has been ChEPS' industrial sponsor since the beginning and saw first-hand how the practice-based model could help learners. Consequently, the company partnered with the Department of Chemical Engineering at KMUTT and created C-ChEPS (Constructionism-ChEPS) in 2000 and C-Pulp in 2001 for its petrochemical and pulp and paper subsidiaries, respectively. In 2007, another collaborative program called PI-ChEPS (Productivity-Improvement ChEPS) involving KMUTT, PTIT, and PTT-Chem was launched. The aim of these three programs is to train and upgrade process operators and technicians at SCG and PTT-Chem, who have years of working experience but only vocational degrees, in the fundamentals of chemical engineering. The hallmark of C-ChEPS, C-Pulp, and PI-ChEPS is the emphasis on project-based learning and the use of "facilitators" (equivalent to site directors in a practice school) to help teach, guide, and advise the trainees. In most cases, these PBL projects come from real-life problems that these trainees encounter on a daily basis. The duration of these special programs is about eight months. This new learning model has been so successful that recently a number of petrochemical and chemical companies in Mathaphut Industrial Estate in the Rayong Province in Thailand have jointly set up V-ChEPS (Vocational-ChEPS), a vocational training institute. The institute grants vocational degrees in several engineering fields and produces qualified vocational personnel to serve the local industries.

As the practice school model gains more traction among educators in Thailand, more academic programs, both new and existing ones, will certainly adopt this new learning approach. KMUTT has considered establishing an undergraduate chemical engineering internship program called U-ChEP (Undergraduate ChEPS) based on the ChEPS model. However, the scale of U-ChEPS will be several times bigger than that of ChEPS, and a number of issues such as manpower must be addressed before U-ChEPS can be successfully launched. Finally, the Thai government has begun to recognize the crucial role of the practice model in higher learning. As a result, the government is now making the practice model one of its initiatives and part of its national policy to develop human resources in Thailand.

Despite the interest and the number of practice-based curricula that exist, the amount of research and their effectiveness on learning and impact on industry, especially at the graduate-school level, is relatively small. One key problem is how to quantify program outcomes and evaluations such as students' satisfaction, the extent of soft-skills acquired, and financial impact on host companies. Comparative studies among engineering practice-based programs are also largely missing. While all practice-based programs share many commonalities, local academic and industrial cultures may entail different kinds of challenges. For example, Asian students tend to be more reserved and passive in classroom and are less likely to question those in authority such as industrial mentors. Another example is how differently public and medium-sized companies operate. Industrial sponsors of some programs such as FEPS are mostly small-to-medium-sized enterprises, and administratively they operate differently from large public companies. Small companies are less rigidly structured, and key decisions regarding practice school sponsorships are often made by the owners or only a handful of people.

A more quantitative study on how to evaluate the practice-based programs is currently underway at the University of Queensland (UQ), Australia. This is a joint PhD research between the two chemical engineering departments at UQ and KMUTT. The objective is to evaluate the two practice-based programs (ChEPS and PEPS) at KMUTT and UQ and conduct a comparative study between the two. The evaluations will be based on the perspectives of the stakeholders, namely the alumni and the sponsoring companies. Possible evaluation methods are in the form of questionnaire surveys and focus group interviews as well as analyses of cost savings in site projects. For example, the alumni would be asked to indicate whether the curricula met their expectations, enhanced their self-confidence, and motivated them to become lifelong learners. On the other hand, sponsoring companies will be asked to grade the alumni who work for them and whether these graduates of the programs possess the skills and attributes needed to succeed as chemical engineers. Other indirect benefits from the university-industry collaboration will also be explored. Finally, the research should help identify areas for improvement as well as organizational and administrative issues that may presently hinder the operation of the programs. As stakeholders, the alumni and the sponsoring companies are also in the best position to offer assistance and solutions for the challenges still facing the programs.

CONCLUSION

MIT in the US has successfully operated its master's degree chemical engineering practice school for nearly 100 years. The uniqueness of the practice model lies in the industrial internship, which trains students to be effective problem solvers. In 1997, KMUTT brought the practice-school model into Thailand as part of a reform initiative to improve the quality of its engineering students and to better serve the needs of industry. Thus, the Chemical Engineering Practice School or ChEPS was born. ChEPS incorporated the essential elements of the MIT model but was expanded to reflect the needs of Thai students. Problem-based learning and work intensity, together with industrial involvement, are the keys that drive the students to excel and contribute to the success of the program.

ChEPS is now in its 14th year since inception, and has since established a reputation as a premier chemical engineering program in the country. Each year, nearly 100 applicants compete for 25 openings. Admitted students are generally ranked in the top 15% of their graduating classes. Surveys have shown that companies sponsoring ChEPS believe the practice-school model to be a win-win partnership between the university and the private sector. The feedback from companies who employ ChEPS alumni is also generally positive.

The success story of ChEPS prompted KMUTT to extend the practice model to other departments, resulting in the creation of more practice schools in food engineering, bioinformatics, starch engineering, and biotechnology. KMUTT has also been able to parlay the practice school model into partnerships with industry, giving rise to many in-house training programs such as C-ChEPS and PI-ChEPS, that upgrade shift operators and technicians in the companies.

Despite the initial success of the practice schools at KMUTT, many challenges remain. The most pressing issue is the long-term sustainability of these programs and how to convince the private sector to contribute more financially. In the end, all parties, namely KMUTT, the government, the private sector, and even the students themselves, must play an active role in ensuring the continued success of the practice school. After all, they are the stakeholders who will reap the benefits that ensue in this partnership.

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KEY TERMS AND DEFINITIONS

Proactive Recruitment: Recruiting new target students, usually seniors, by staging roadshows and on-campus presentations at the departmental level.

Practice-Based learning (PBL): A teaching model that emphasizes solving real-life problems through collaboration with industry.

Practice School: A curriculum, usually in science and engineering, which incorporates problem-based learning and involves industrial projects.

Practice Station: A sponsoring company, usually a plant in the field of chemical engineering, where students are interned and receive practical training.

Site Director: A faculty member from the practice school who is permanently stationed at a practice station and work closely with industrial sponsors and students on site projects.

Soft Skills: Additional attributes that engineers should possess, such as teamwork, presentation, written, and awareness skills.

Work-Integrated Learning: A student-centric learning process that integrates theoretical learning with its application in the workplace while emphasizing work readiness, creative thinking, life-long learning, and other desirable soft skills.